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“Knowledge is such a treasure which cannot be stolen”



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IS : 7410 ( Part I ) - 1974

*Indian Standard*

GUIDE TO THE USE OF  
PIEZOELECTRIC FILTERS

PART I QUARTZ CRYSTAL FILTERS

( First Reprint December 1996 )

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**BUREAU OF INDIAN STANDARDS**

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NEW DELHI 110002

**Gr 6**

*March 1975*

**AMENDMENT NO. 1 APRIL 1981**

**TO**

**IS:7410 (PART I)-1974 GUIDE TO THE USE  
OF PIEZOELECTRIC FILTERS  
PART I QUARTZ CRYSTAL FILTERS**

**Alterations**

*(Page 4, clause 2.1, line 2) - Substitute  
'IS:1885 (Part XLIV)-1978\*' for 'IS:1885 (Part V)-  
1965\*'.*

*(Page 4, foot-note with '\*' mark) - Substitute  
the following for the existing foot-note:*

**'\*Electrotechnical vocabulary:Part XLIV  
Piezoelectric devices. [Superseding  
IS:1885 (Part V)-1965 and IS:1885 (Part XXXIII)-  
1972].'**

**(LTDC 12)**

# *Indian Standard*

## GUIDE TO THE USE OF PIEZOELECTRIC FILTERS

### PART I QUARTZ CRYSTAL FILTERS

Piezoelectric Crystals for Frequency Control and Selection  
Sectional Committee, ETDC 51

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( Continued on page 2 )

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( Continued from page 1 )

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## *Indian Standard*

# GUIDE TO THE USE OF PIEZOELECTRIC FILTERS

## PART I QUARTZ CRYSTAL FILTERS

### 0. FOREWORD

**0.1** This Indian Standard ( Part I ) was adopted by the Indian Standards Institution on 26 July 1974, after the draft finalized by the Piezoelectric Crystals for Frequency Control and Selection Sectional Committee had been approved by the Electrotechnical Division Council.

**0.2** Electrical filters are widely used in communication, telemetry, navigation and measurement applications. In many cases, the amplification and the filtering are combined as in the case of interstage transformers between active devices, such as tubes or solidstate devices. Recent demands for sharper selectivity, flatter passband characteristics, higher stop band attenuation, higher stability and lower ageing have resulted in increasing use of filters as independent units separated from amplifiers. The advent of integrated circuits has accelerated this trend.

**0.3** The qualities of a filter are mainly governed by the characteristics of the resonant elements used in the filter. Piezoelectric resonators are superior to conventional LC resonant circuits with regard to such characteristics as the quality factor (  $Q$  ), temperature characteristics, ageing rate, size and weight. Hence, a wide variety of piezoelectric filters is now available commercially.

**0.4** There are two main types of piezoelectric filters: one is quartz crystal filter and the other ceramic filter. There are certain similarities as well as dissimilarities between these two types of filters. Two standards have been prepared in response to a generally expressed desire on the part of both the users and the manufacturers for a guide to the use of piezoelectric filters, so that the filter may be used to its best advantage — the first one ( this standard ) relates to quartz crystal filters and the second relates to ceramic filters [ see IS : 7410 ( Part II ) ]\*.

**0.5** This standard is limited to passive bandpass filters operating over the frequency range from about 10 kHz to 100 MHz which are commercially available as separate and independent units. Filters which are

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\*Guide to the use of piezoelectric filters: Part II Piezoelectric ceramic filters ( under preparation ).



## **IS : 7410 ( Part I ) - 1974**

integrated into a larger system are not covered by this standard. Filters considered in this standard are limited to two-port filters using passive linear elements.

**0.6** It is not the aim of this standard to explain theory, nor to attempt to cover all the eventualities which may arise in practical circumstances. This guide draws attention to some of the more fundamental questions which should be considered by the user before he places an order for a unit for a new application. Such a procedure will be the user's insurance against unsatisfactory performance.

**0.7** While preparing this standard assistance has been derived from the following publications issued by the International Electrotechnical Commission:

IEC Pub 368A 'First supplement to Publication 368 ( 1971 ) Piezo-electric filters '.

IEC Doc: 49( C.O. ) 78 Draft — Check list for crystal filters.

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### **1. SCOPE**

**1.1** This standard ( Part I ) deals with the use of **piezoelectric** quartz crystal filters so that the filters may be used to its best advantage.

**1.2** The scope is limited to passive bandpass filters in the frequency range from about 10 kHz to 100 MHz, which are commercially available as separate and independent units. Filters which are integrated into a larger system are not covered by this standard.

### **2. TERMINOLOGY**

**2.1** For the purpose of this standard, the terms and definitions given in IS : 1885 ( Part V )-1965\* shall apply.

### **3. GENERAL**

**3.1** The high  $Q$  and the high stability of quartz crystal resonators have been used in obtaining very selective electrical filters, which are commonly called crystal filters. Crystal filters are now widely used in communication, telemetry, navigation and measurement as well as in long distance carrier systems. Although their specifications are very diverse, many of these needs may be served by a few standard types of crystal filters.

**3.2** Standard article sheets, or the data sheets issued by manufacturers will define the available combinations of reference frequency,

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\*Electrotechnical vocabulary: Part V Quartz crystals.

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1972].'

(LTDC 12)



passbandwidth, ripple, shape factor, terminating impedance, etc. These sheets are compiled to include a wide range of piezoelectric quartz crystal filters with standardized performances. It should be emphasized that the user should, wherever possible, select his crystal filters from these sheets, when available, even if it may lead to making small modifications to his circuit to enable standard filters to be used. This is especially so in the selection of reference frequency.

**3.3** In contrast to conventional LC filters, quartz crystal filters offer substantial advantages in design and production costs, when their reference frequencies are limited to a few narrow frequency ranges. Hence, an order which does not specify one of the more commonly used reference frequencies may be uneconomical.

**3.4** It should be understood, that standardization is not a fixed, but rather a continuing process. As new requirements arise, new article sheets will be produced to meet these requirements, after careful consideration.

#### **4. TECHNICAL INTRODUCTION**

**4.1** It is of prime interest to a user that the filter characteristics should satisfy a particular specification. The selection of internal filter and resonator networks to meet that specification should be at the option of the manufacturer.

**4.2** The amplitude versus frequency characteristics of a filter are usually expressed in terms of transducer attenuation as a function frequency, as shown in Fig. 1. A standard method for measuring transducer attenuation is described in 8. In some applications, such characteristics as transient response or group delay are more important than transducer attenuation. But these special characteristics are not considered here.

**4.3** Transducer attenuation characteristics are further specified by reference frequency, minimum transducer attenuation, passband ripple and shape factor. The specification is to be satisfied between the lowest and the highest temperature of the specified operating temperature range. This condition shall also be satisfied before and after environmental tests.

#### **5. QUARTZ CRYSTAL RESONATORS FOR FILTERS**

**5.1** A brief description of crystal resonators is included here, so that a user may understand the feasibility and the limitation in the design of crystal filters due to the characteristics of resonators. In a conventional filter, inductors and capacitors are used as reactive elements. The inevitable losses associated with the components yield twofold effects on filter characteristics. Firstly, the transducer attenuation becomes finite instead of zero in the passband. Secondly, and more serious, the sharpness of the attenuation characteristic near the cutoff frequency may

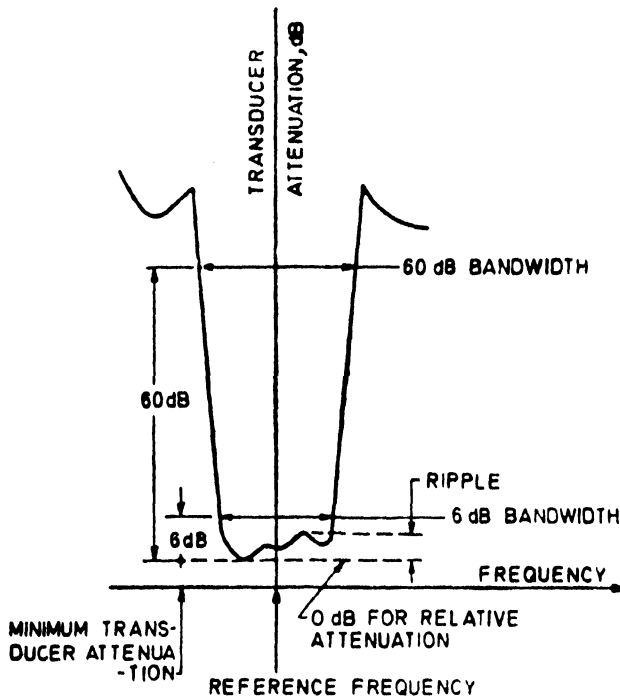


FIG. 1 TRANSDUCER ATTENUATION CHARACTERISTICS OF A FILTER

be spoiled. The second effect mostly depends on the  $Q$  of components, whereas the first effect depends, among other things, on absolute values of dissipation.

**5.2** A quartz crystal resonator is equivalent to a combination of reactive elements with a quality factor ( $Q$ ) which is at least two orders of magnitude better than the  $Q$  of conventional inductors. A crystal filter uses quartz resonators in place of inductors and capacitors and takes advantage of the high  $Q$  of resonators to achieve sharpness of cutoff. Figure 2 shows a typical comparison of a crystal filter with a conventional filter, both of which are designed to have similar passbands. It can be seen that much sharper cutoffs and sharper attenuation peaks are obtained by the use of crystal resonators, whereas there is little improvement in the minimum insertion loss. The use of crystal resonators in a filter also yields additional advantages, such as better temperature and ageing characteristics, small size and lighter weight.

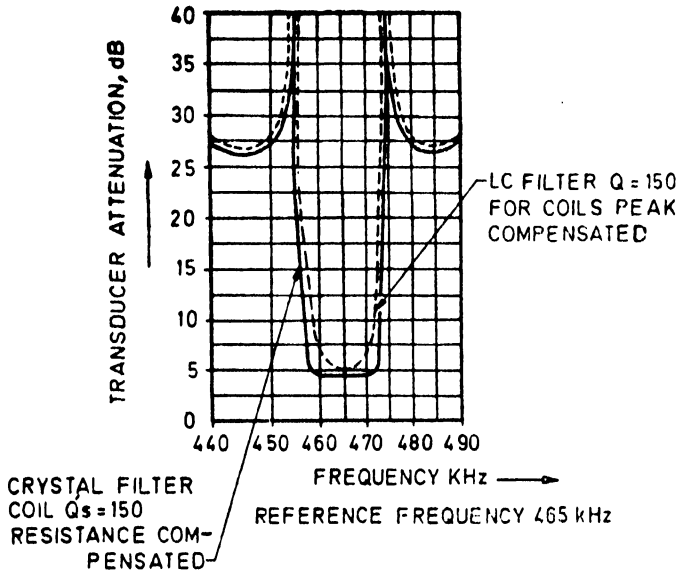


FIG. 2 COMPARISON OF CHARACTERISTICS OF A CRYSTAL FILTER AND A CONVENTIONAL LC FILTER

**5.3** The electrical characteristics of a crystal unit may be represented by means of the equivalent circuit shown in Fig. 3. It consists of a shunt capacitance  $C$  and a dynamic branch comprising equivalent inductance  $L_1$ , capacitance  $C_1$  and resistance  $R_1$  in series. Other convenient parameters for discussing characteristics of crystal units for filters are resonant frequency  $f_s$ , antiresonant frequency  $f_p$ , quality factor  $Q$ , and capacitance ratio  $r$ , which are defined also in Fig. 3.

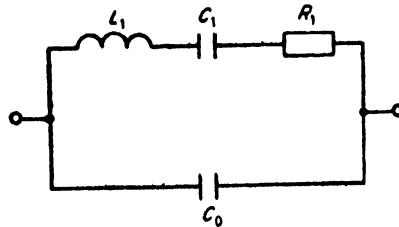


FIG. 3 EQUIVALENT CIRCUIT OF A CRYSTAL UNIT

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**5.4** There are a few important differences between crystal units for filters and crystal units for oscillators. With a crystal unit for use in oscillators, the temperature coefficient and the effects of ageing on the resonant frequency and the  $Q$  are of prime interest. They are also important in the case of a filter crystal unit but to a smaller degree. Theoretically, these determine the lower limit of the usable bandwidth of a crystal filter. The bandwidth of the majority of filters is usually far wider than this limit.

**5.5** In the case of a crystal unit for a filter, it is further required that all the reactance parameters are to be specified in a design. These parameters are determined by such factors as the dimensions of the resonator, the shape and the location of electrodes, and the mode of vibration. Since these factors cannot be chosen arbitrarily, the available range of the parameters is relatively restricted in comparison with the range of conventional inductors.

For example:

- a) The range of available equivalent inductances at a particular frequency does not exceed about 50 : 1 anywhere and for high frequency crystals may not be as much as 5 : 1, compared with a range of 1 000 or more for acceptable conventional inductances or capacitances at a particular frequency. This imposes severe limitations on the design of a crystal filter.
- b) The high value of the equivalent inductances is a further practical difficulty.

**5.5.1** Table 1 presents characteristics of typical crystal units for a low frequency ( 100 kHz ) and a high frequency ( 10.7 MHz ), respectively. The capacitance ratio  $r$ , is the ratio of the shunt capacitance to the equivalent dynamic capacitance. The value of the capacitance ratio can be modified by the adjustment of the electrode configuration, but cannot be lower than a certain minimum value, which is an inherent constant of a mode of vibration.

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**TABLE 1 CHARACTERISTICS OF CRYSTAL UNITS**

FREQUENCY	EQUIVALENT DYNAMIC INDUCTANCE	$Q$	MINIMUM CAPACITANCE RATIO, $r$
(1)	(2)	(3)	(4)
100 kHz	20-100 H	50 000	130
10.7 MHz	10-30 mH	150 000	250
21.4 MHz	←—Under consideration—→		

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**5.5.2** The ratio is also a measure of the separation between the resonant and the antiresonant frequencies as shown below:

$$\frac{f_p - f_s}{f_s} = \left[ \sqrt{1 + \frac{1}{r}} \right] - 1 \approx \frac{1}{2r}$$

Thus, the capacitance ratio is closely related to the bandwidth of a crystal filter.

**5.6** With a filter consisting of crystal units and capacitors, the widest fractional passbandwidth obtainable is  $(1/r)$ . If much wider passbandwidths are required, inductors may be employed as well as crystal units and capacitors. A fractional passbandwidth up to  $(2/r)^{\frac{1}{2}}$  may be obtained. Inductors may be placed in such positions in the circuit as to render possible combination of their losses with those of the load resistances, with the result that the effect of the losses causes only an additional constant attenuation without affecting the sharpness of cutoff.

**5.7** Because a crystal resonator has a complex mechanical structure, there are numerous modes of vibration other than the main mode which is intended for use in a filter. These modes sometimes occur in the vicinity of the main mode and disturb filter characteristics. Such unwanted modes shall be suppressed below a certain level or shifted to frequencies which are of no importance.

**5.7.1** This requirement is more important for filter crystal units than for crystal units for oscillators. It is usually met by suitable design of the dimensions of the resonator, the electrodes and the mounting. It is for this reason that the available range of equivalent circuit parameters is more restricted.

**5.8** A resonator with more than one pair of electrodes is sometimes used. There are also resonators utilizing more than one main mode of vibration. Such multiple-electrode or multiple-mode resonators offer some advantages in the practical construction of a filter, although they introduce a little fundamental change in the feasibility and limitations of crystal filters.

**5.9** In high frequency crystal resonators, the vibration energy can be trapped in the vicinity of an electrode by the loading mass of the electrode. A multiple-mode resonator or an electromechanical filter can be obtained by utilizing mutual acoustic coupling between several regions energized by different electrodes. Thus a complete filter can be obtained in a monolithic or integrated form. This makes possible substantial reductions in size and weight.

## 6. BASIC FILTER CHARACTERISTICS

**6.1 General Characteristics** — The following is a brief summary of the characteristics of individual types of filter using passive linear elements.



It should be noted that a crystal discriminator can be regarded as a specific form of a filter incorporating non-linear devices. There are also filters using active elements. Both of these are outside the scope of this guide.

### 6.1.1 Single Side Band (SSB) Filters

**6.1.1.1** These may have either symmetrical or asymmetrical attenuation characteristics depending on whether the equipment uses a single carrier frequency or two alternative carrier frequencies, one on each side of the passband. The passbandwidth ( typically at 6 dB ) will lie between about 2.4 kHz and 3.5 kHz depending on the application.

**6.1.1.2** The volume of such filters varies from 30 to 150 cm<sup>3</sup> in the 1 to 2 MHz range to values as low as 16 cm<sup>3</sup> at 9 MHz. Typical relative stop band attenuation is 60 dB. An example of a filter with 6 dB at 2.5 kHz bandwidth and 60 dB at 3.6 kHz bandwidth, with a load impedance of 75 or 5000 ohms is given in Fig. 4.

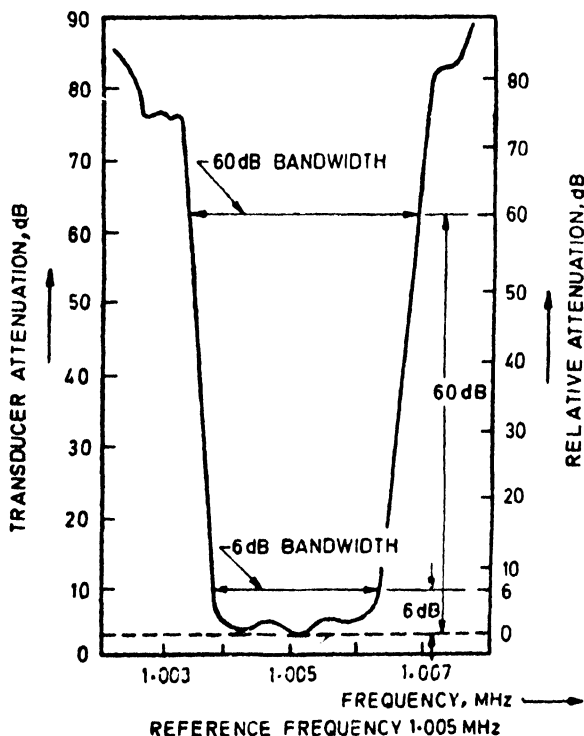


FIG. 4 EXAMPLE OF A 1.005-MHz CRYSTAL FILTER FOR SSB DUPLEX EQUIPMENT

**6.1.1.3** The difficulty of producing these filters is largely a function of the transition bandwidth between the passband and the stop band, particularly as regards the requirement for carrier suppression including the effect of temperature.

**6.1.2 *Filters for FM Applications***

**6.1.2.1** These are usually for 10·7 MHz, although other frequencies may be in common usage, such as over the frequency range 8 to 30 MHz.

**6.1.2.2** Passbandwidths are specified wide enough to pass the audio signals on the carrier under conditions of varying temperature and errors in both transmitter and receiver oscillator frequencies. The permissible errors of these frequencies are normally laid down by the responsible authorities.

**6.1.2.3** Stop band and transition band attenuations are determined by the position of the next channel and its frequency stability together with the frequency spectrum produced by the superimposed signal modulation. The adequacy of performance may be determined by a two signal test which checks the interference and cross talk on a wanted channel caused by a signal in an adjacent channel are measured.

**6.1.2.4** Typical filters require loads of 1 000 ohms shunted by 25 pF. It is necessary to ensure that tolerances on the loads are not too wide, so as to avoid undesirable passband ripples which may result in unacceptable distortion or sensitivity to interference or both.

**6.1.2.5** Volumes of filters are usually in the range 10 to 40 cm<sup>3</sup> with relative attenuations of 50, 80 or 90 dB depending on the application and on whether the filter provides all or only a part of the receiver selectivity required.

**6.1.2.6** Normally, special filter passband characteristics are not specified for FM systems. An example of this is illustrated in Fig. 5, which is an example with 6 dB maximum specified at  $\pm 15$  kHz and 80 dB minimum specified at  $\pm 30$  kHz.

**6.1.3 *Band Stop Filters*** — Band stop filters are not easily made with asymmetrical stop band characteristics but this is rarely a requirement. Multiple band stop filters with bandwidths of more than 0·1 percent and substantial attenuation are rare and difficult to make. Unwanted responses can be troublesome unless the stop bandwidth is narrow because they introduce losses in the passband. Further difficulties due to inductor imperfections are experienced with very wide passbands extending to frequencies of one or more orders of magnitude greater than the stop band frequencies.

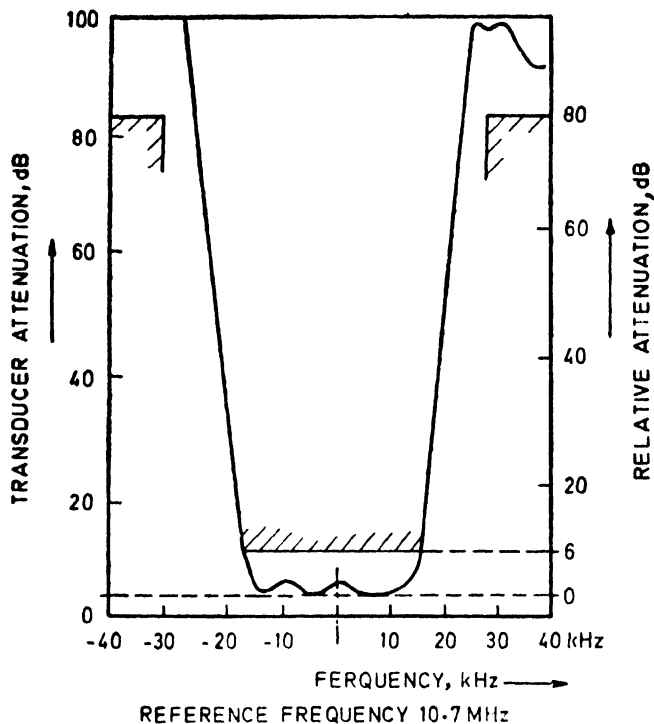


FIG. 5 EXAMPLE OF A 10.7-MHz CRYSTAL FILTER  
FOR 50 KHz CHANNEL SPACING

**6.1.4 Response Characteristics** — For filters where the form of amplitude characteristics is important, there exist such theoretical response characteristics as the Chebyshev maximally flat or extra-flat (Butterworth), Papoulis, elliptic functions response, etc. Where the phase characteristic is more important, such as in digital transmission systems, there exists Gaussian function response. It is not good practice to specify the response of the filter solely in terms of these characteristics because they are theoretical in nature and practical filters can only approximate to the ideal response due to the spread between the resonator parameters, according to the real terminations, etc. It should also be noted that since there is a relationship between phase and amplitude characteristics, it is not possible to obtain both characteristics independently.

## 6.2 Availability and Limitations

**6.2.0** Crystal filters are manufactured in quantity and widely used for selectivity in all classes of equipment where the first IF is in the high frequency range. Types exist for FM applications at, for example, 10.7 MHz for VHF and UHF bands for 50, 25, 20 and 12.5 kHz channel spacing. An example of a 50-kHz channel spacing filter is given in Fig. 5.

**6.2.0.1** Filters exist also for some single sideband applications with filter frequencies below 10 MHz. An example of a filter at 1.005 MHz for duplex single side band communication is given in Fig. 4.

**6.2.0.2** In addition, crystal filters are firmly established in frequency division multiplexing telephony systems for channel selection, pilot signal rejection and selection, and carrier supply requirements, although these are not usually available in the market. Details of available bandwidths are discussed in 6.2.1.

### 6.2.1 *Effect of Bandwidth on Availability of Crystal Bandpass Filters*

**6.2.1.1** The available parameters of quartz crystal units affect the characteristics of the filter unit and thus impose constraints on the design of the filter. Most crystal filters used are characterized by their bandpass. Figure 6 is a graphical representation in terms of reference frequency *versus* bandwidth of crystal bandpass filters which can be produced without difficult development work. It should be borne in mind that this chart is a guide only to what is technically possible. Commercial availability will depend on other factors, such as quantity, environmental requirements, size and cost.

**6.2.1.2** The following clarify the reasons on account of which in certain regions ( *see* Fig. 6 ) there are difficulties relating to the bandwidths available at different reference frequencies, and they apply to filters which have symmetrical or asymmetrical attenuation characteristics:

- a) *Region of Q and frequency stability problems* — In this region, the crystal units normally available will have Q's and stabilities which will produce difficulties due to one or more of the following:
  - 1) Very high value of minimum transducer attenuation or change with temperature or both,
  - 2) Change in characteristic with time due to crystal ageing,
  - 3) Inconsistency of passband shape between samples, and
  - 4) Variation of mid-band frequency with temperature.

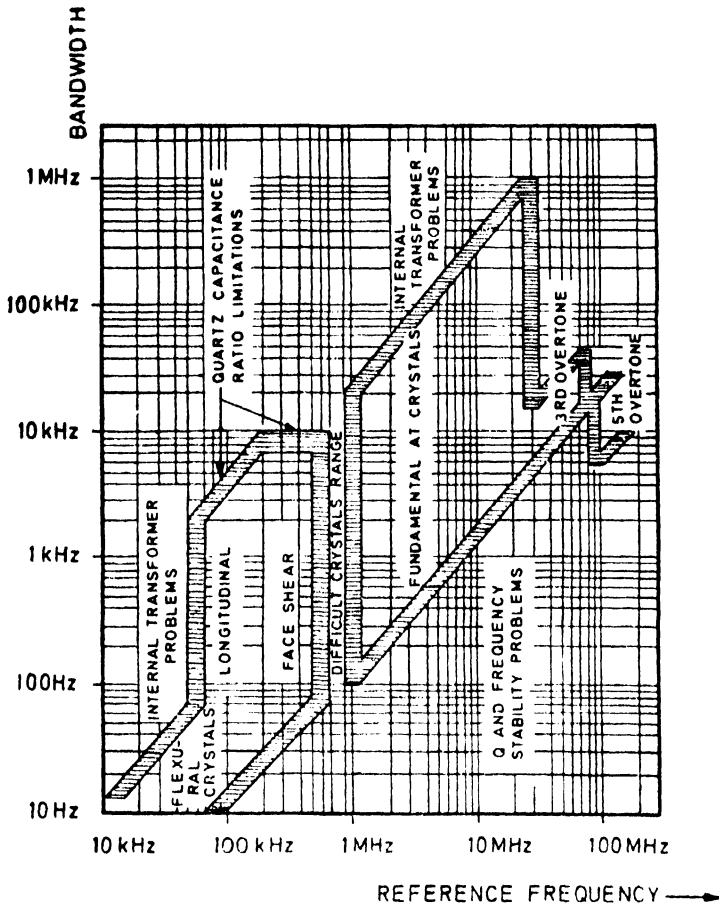


FIG. 6 FREQUENCY RANGES OF CRYSTAL BANDPASS FILTERS  
( NOT REQUIRING CRITICALLY DIFFICULT DEVELOPMENT )

- b) *Region of internal transformer problems* — In this region, the  $Q$  and temperature coefficient of transformers become critical and it may be impossible to obtain adequate stability with time and temperature or adequate shunt resistance to terminate the filter correctly.
- c) *Region of quartz capacitance ratio limitations* — It is difficult to use this range irrespective of the circuitry used with passive components. The dividing line depends to some extent on the quality of internal transformers with respect to self-capacitance.

- d) *Region of difficult crystal frequency range* — This range should be avoided if possible since such crystals are expensive, of high impedance, have difficulties in reproducibility of characteristics between one sample and another, and even small changes of reference frequency may require extensive development work to establish a satisfactory design.

**6.2.2 Passbandwidth** — As the passbandwidth varies, the choice of network configuration to be used also changes. There are three types of configuration which are usually described as having:

- a) narrow passbandwidth,
- b) intermediate passbandwidth, and
- c) wide passbandwidth.

The principle characteristics and limitations of these types are described in 6.2.2.1 and 6.2.2.2.

**6.2.2.1 Narrow pass bandwidth filters** (for example, up to a fractional pass-bandwidth up to  $\frac{1}{r}$ ) — These may be of ladder, lattice or hybrid configuration.

They contain transformers and inductors only for the purpose of matching the impedance to the load, or for conversion from unbalanced conditions in the filter. The transformers may also be used to augment the stop band characteristics at frequencies away from the immediate passband region.

**6.2.2.2 Intermediate passbandwidth filters** (for example, from a fractional pass-bandwidth of  $\frac{1}{r}$  to  $\frac{4}{r}$ ) — These differ from the previous type only in that finite but non-critical inductances are required to tune out crystal capacitance and/or load capacitance in order to give the correct response.

This can lead to degradation of the passband response, particularly near the upper cutoff due to the  $Q$  of the added inductors; another modification may be observed some distance from the passband due to the presence of the inductors which may either increase or reduce the theoretical attenuation. Otherwise available characteristics are similar to those for narrow bandwidth filters.

**6.2.2.3 Wide passbandwidth filters** (for example, from a fractional pass-bandwidth of  $\frac{4}{r}$  to  $(2/r)\frac{1}{2}$ ) — These differ considerably from either of the previous types by utilizing inductances which require accurate values and which are incorporated specifically in the design not only to tune out crystal capacitances which otherwise would prevent the correct bandwidth being obtained, but also to assist in achieving the required stop band relative attenuation.

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The inductors are so positioned in the filter configuration that their  $Q$  only results in a constant increase in transducer attenuation. The end inductor may be in shunt or series with the load resistance.

The minimum transducer attenuation of this type of filter in decibels is approximately proportional to the inverse of the fractional bandwidth for a specified  $Q$  of the inductances added to the crystal structure.

### **6.2.3 *Limitations on Temperature Performance***

**6.2.3.1** Narrow band filters will possess a temperature performance which is almost independent of that of any associated inductances. The performance will be mainly determined by the temperature coefficient of the crystals and to a first order the effect will be confined to a variation of the mid-band frequency in relation to the variations of the crystals. Since most crystals do not have a linear temperature coefficient, measurement at a substantial number of temperatures may be necessary to obtain accurate data.

**6.2.3.2** For very narrow bandwidths, differences in temperature characteristics of the crystals within the filter may result in variations of ripple magnitude with temperature, and if large temperature coefficients for the capacitors are used, as might occur if ceramic capacitors are used, the bandwidth may also vary with temperature.

**6.2.3.3** For crystals used below approximately 1 MHz, variation of the equivalent resistance of the crystal with temperature will affect the minimum transducer attenuation considerably. This is important for pilot selection filters. As the bandwidth increases into the intermediate bandwidth region, the temperature coefficient of the inductance becomes important and can affect ripple and bandwidth.

**6.2.3.4** For wideband filters, the main effects will be upon passband shape due to the temperature coefficient of the added inductances and their associated capacitances and upon stop band attenuation dependent on the temperature coefficient of capacitances used for positioning the attenuation peaks in the correct position. The effect of crystal temperature coefficient is likely to be minor.

**6.2.3.5** Filters for mobile equipment normally fall into the boundary between the narrow bandwidth and intermediate bandwidth regions. The wide temperature ranges in many specifications require careful attention to the temperature coefficient of the crystals and to the temperature coefficient of the inductances and associated capacitors.

**6.2.3.6** Single side band filters generally have more severe requirements than double side band filters due to the narrow transition range between the wanted and unwanted side bands, and to carrier frequency rejection. Even with carefully controlled high frequency crystals, the upper limit is about 25 MHz for practicable filters.

#### **6.2.4 Limitations on Environmental Performance**

**6.2.4.1** Since crystal resonators may not be completely immersed in encapsulant, special consideration should be given to environmental aspects. Since virtually no vibrational energy reaches the edge of high frequency plates, these crystals can be mounted at the edges.

**6.2.4.2** For low frequency contour modes, the problem is more difficult since strain of the support wires can affect frequency stability and resistance. It is important therefore that the correct environmental requirements are specified before design rather than later.

**6.2.4.3** For filters to be used in mobile equipment, vibration specifications of 10g for prolonged periods at frequencies up to 500 cycles, bump tests at 40g and acceleration tests at 13g, do not present difficulties.

**6.2.4.4** Resistance to shock and vibration tests may be a function of direction of application. Where requirements are severe, it may be possible to optimize the filter unit with this in mind.

#### **6.2.5 Other Limitations**

- a) *Transducer Attenuation* — This is not necessarily lower than for an LC filter of the same bandwidth. It can be higher due to difficulties caused by crystal parameters.
- b) *Unwanted Responses* — These can be troublesome in some cases as discussed in 5.
- c) *Sensitivity to Load Impedance Errors* — This may be greater than for an LC filter. This is a function of the configuration and design technique used. If important, the effect of errors should be evaluated.

#### **6.2.6 Standardization**

**6.2.6.1** Since there are many more possible points of difference between various crystal filters than between other components which do not consist of an assembly of elements, it is not possible at the present time to standardize size, shape, reference frequency and other characteristics.

**6.2.6.2** Some degree of similarity does exist between various units used in the first IF of an equipment which is at, for example, 10.7 MHz. However, differences may exist between products of different filter suppliers with particular reference to terminating impedances. Even then



## IS : 7410 ( Part I ) - 1974

manufacturers requirements differ for one or more of the following reasons:

- a) *Application* — Some requirements specify that these filters provide all the relative attenuation required, others augment it at a second intermediate frequency ( IF ). For some applications, size is critical, for example, pocket sets, while for others, cost is dominant. Such applications may require different minimum relative attenuation performance.
- b) *Channel spacing* — 50, 25, 20 and 12.5 kHz channel spacings are now common, but 60 and 30 kHz also exist. Even with a particular channel spacing, the characteristics required are a function of the local oscillator stability used.
- c) *Modulation* — Bandwidth requirements for FM and AM may differ.
- d) *Impedance* — In general, filters are designed to operate between specific terminating impedances.
- e) *Local oscillator stability* — The passbandwidth required of the filter will be partly determined by the local oscillator stability combined with any drift of the equipment.

**6.3 Input Levels** — Drive level performance may be limited by reason of:

- a) crystal resonator damage,
- b) crystal resonator frequency and/or activity change,
- c) inductance change, and
- d) intermodulation requirements.

**6.3.1 Crystal Resonator Damage** — This may be dependent on signal frequency and whether the filter is correctly loaded. Sensitivity to high drive levels will be highly dependent on resonant frequency of the crystal elements. Even if normal conditions are satisfactory, the implications of testing and other abnormal conditions, such as the filter being open-circuited at the output terminals should be considered, since this could result in substantially greater power reaching the resonator.

**6.3.1.1** The input impedance of a filter in the stop band may vary considerably, hence levels in the stop band should be expressed in terms of equivalent source potential.

**6.3.2 Change in Crystal Resonator Frequency or Resistance or Both** — The maximum levels at which the filter is required to operate within limits should be stated. For very narrow bandwidths this will be more important than for wider bandwidth filters due to the greater frequency

stability required. Filters using low frequency crystals should not be subjected to drive levels in excess of 1 mW when correctly terminated unless the manufacturer specifically agrees to it. For filters using resonators in thickness sheer mode drive levels up to 10 mW when correctly terminated are normally acceptable. Very low drive levels can be experienced in communication receivers. Characteristics of filters are not normally affected by operating at the low levels which may be below 1 pW.

**6.3.3 Inductance Changes** — These are usually negligible for high frequency filters, but should be considered for low frequency filters. Where dc is passing through the input or output filter transformer, the direct current level should be specified.

## 7. APPLICATIONS AND PRACTICAL REMARKS

**7.1** The most extensive applications of standard type crystal filters are seen in intermediate frequency filtering and in single sideband generation, although there are numerous important applications in navigation, telemetry and measurement as well as carrier systems. For example, the high selectivity of an IF crystal filter makes a single conversion receiver as shown schematically in Fig. 7 possible. The characteristics of a crystal filter are governed largely by the network inside the unit.

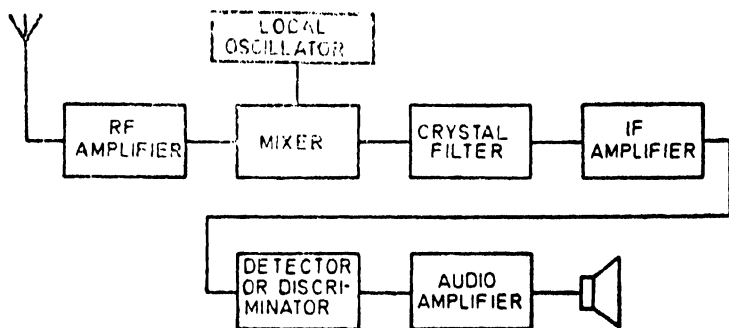


FIG. 7 SINGLE CONVERSION RECEIVER

**7.2** Certain precautions, however, are required in order to obtain a satisfactory performance, when the filter is inserted between external circuits, especially between active devices. The following are important:

- a) Both input and output terminals of a filter should be properly loaded by specified resistances. At a high frequency it is frequently required that stray capacitances are kept below

specified values or sometimes are adjusted to certain specified values. Figure 8 shows the characteristics of a 10.7-MHz filter loaded by resistances of 10 k $\Omega$  and 15 k $\Omega$ . The filter was designed to be loaded by 15 k $\Omega$ . Figure 9 shows characteristics of the same filter, which is loaded by correct resistances, before and after the insertion of stray capacitances of 5 pF in both input and output terminations. Considerable distortions in the passband due to improper loads can be observed in both figures.

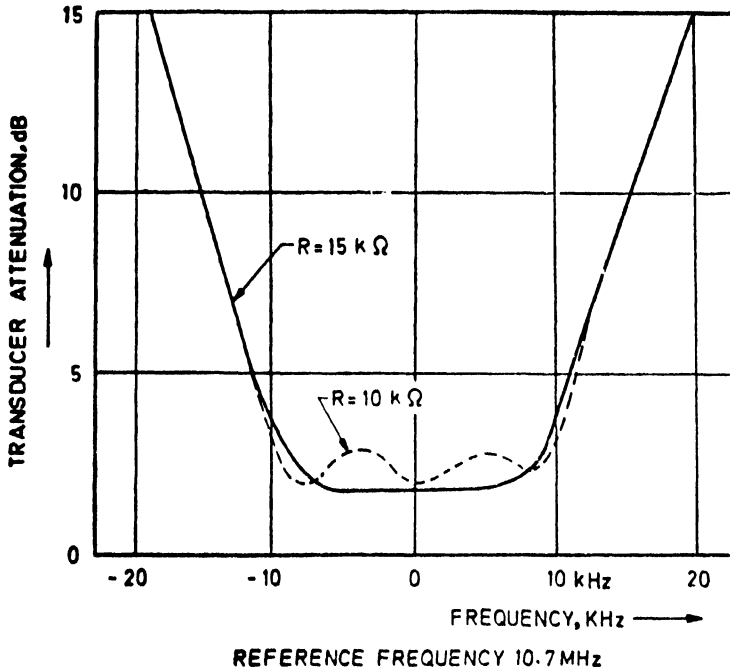


FIG. 8 EFFECT OF LOAD RESISTANCES ON THE CHARACTERISTICS OF A CRYSTAL FILTER

- b) Stray coupling between input and output terminals should be kept to a minimum by proper earthing or shielding. Otherwise the guaranteed loss at the stop band may not be obtained. Figure 10 shows that a stray coupling of only 0.5 pF greatly reduces the attenuation of a 10.7-MHz filter in the attenuation bands.
- c) The level of input signal should be kept below a specified value. Overdriving tends to create various undesirable effects. This precaution is especially necessary when a filter is used in a transmitter for the generation of single side band signal.

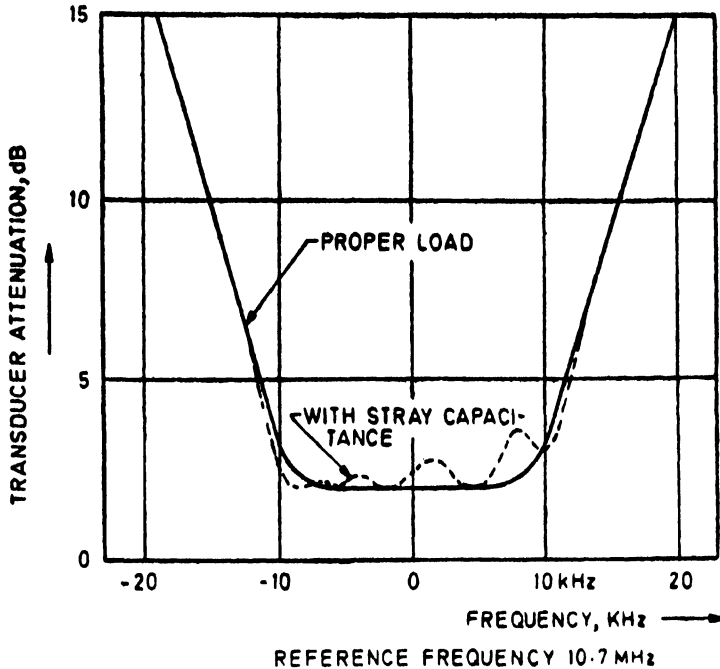


FIG. 9 EFFECT OF LOAD CAPACITANCES ON THE CHARACTERISTICS OF A CRYSTAL FILTER

- d) In many cases, transformers are used in a crystal filter to obtain proper impedance conversion. These transformers may not be suitable for the application of direct voltages and care should be exercised before such connections are used.

## 8. MEASURING TECHNIQUES

8.1 The measuring techniques shall be in accordance with IS : 6133 ( Part I )-1971\*.

## 9. MARKING

9.1 Marking which shall be in line with 6 of IS : 6133 ( Part I )-1971\* includes type number, reference frequency and mark of origin with additional marking to be agreed upon between customer and manufacturer.

\*Specification for piezoelectric filters for use in telecommunication and measuring equipment: Part I General requirements and tests.

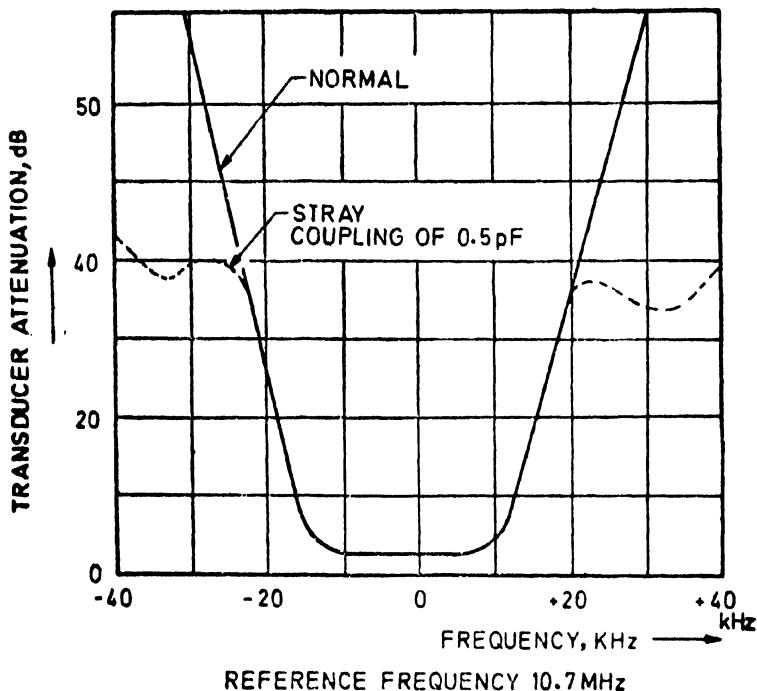


FIG. 10 EFFECT OF STRAY COUPLING ON THE CHARACTERISTICS OF A CRYSTAL FILTER

## 10. ORDERING PROCEDURE

**10.1** When the requirements are to be met by a standard item, it will be sufficient to specify the corresponding article sheet.

**10.2** When the requirements cannot wholly be met by an existing article sheet, the article sheet should be quoted together with known differences.

**10.3** In a rare case, where the differences are such that it is not reasonable to quote an existing article sheet, a new sheet is to be prepared in a similar form to that already used for standard article sheets.

**10.4** A suitable check list ( *see* Appendix A ) will be useful for ordering a crystal filter and should be considered in drawing up a specification.

**10.5** In an unsymmetrical filter, it is recommended that the stop band and passband requirements be specified with reference to precise frequencies rather than by quoting bandwidths in both regions.

**10.6** It should be clearly stated in the specification whether the filter is required to operate whilst under conditions of shock, vibration or acceleration. If it is, the possibility of noise generation and its acceptable limit should be considered, but is only of concern for lower frequency filters.

## **A P P E N D I X   A**

( *Clause 10.4* )

### **CHECK LIST FOR ORDERING PIEZOELECTRIC QUARTZ CRYSTAL FILTERS**

#### **A-1. APPLICATION**

( For example, for stationary, portable or aircraft equipment, etc )

#### **A-2. DESCRIPTION**

( Desired volume or outline )

#### **A-3. MANDATORY REQUIREMENTS**

##### **A-3.1 Electrical**

- a) *Reference frequency*
- b) *Passbandwidth characteristics*
  - 1) Bandwidth ( at ... dB )
  - 2) Maximum ripple
  - 3) Maximum transducer attenuation
  - 4) Shape factor ( at ... dB and ... dB )
  - 5) Minimum relative attenuation within stop band ( from .. Hz to ... Hz )
  - 6) Magnitude and nature of input and output terminating impedances

##### **A-3.2 Environmental**

- a) *Temperature range*
  - 1) Operating
  - 2) Operable
  - 3) Storage

## **A-4. OPERATIONAL REQUIREMENTS**

### **A-4.1 Electrical**

- a) Unwanted responses
- b) Maximum level
- c) Input level
- d) Insulation resistance
- e) Other requirements ( for example, phase characteristics, ageing, etc )

### **A-4.2 Environmental Requirements**

- a) *Climatic*
  - 1) Humidity
  - 2) Others ( for example, sealing, temperature cycling )
- b) *Mechanical*
  - 1) Bump
  - 2) Shock
  - 3) Vibration
  - 4) Acceleration

### **A-4.3 Physical Requirements**

- a) Type number of ISI standard filter outline ( if any )
- b) Length
- c) Width
- d) Height
- e) Terminals and mounting accessories
- f) Markings
- g) Weight
- h) Others ( such as solderability )

## **A-5. INSPECTION REQUIREMENTS**

- a) Related specifications
- b) Inspection authority
- c) Acceptable quality levels
- d) Type tests
- e) Others

**NOTE** — It is also necessary to include the severity of the testing required, that is, how often the test shall be performed, the percentage to be tested and the acceptable failure rate.

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